

AMENDMENTS TO THE CLAIMS

This listing of claims will replace all prior versions and listings of claims in the application.

1 1. (Currently Amended) A ~~computer implemented~~-method of determining lower and
2 upper bounds for a minimum cost of placing data objects onto nodes of a distributed
3 storage system while meeting a performance requirement for a workload comprising
4 the steps of:

5 solving an integer program using a relaxation of binary variables to
6 determine the lower bound, the binary variables having values between zero
7 and one comprising a first subset;

8 for the binary variables in the first subset and until no binary variables
9 remain in the first subset, iteratively performing the steps of:

10 rounding up a first binary variable having a lowest ratio of a cost
11 penalty to a performance reward; and

12 until no binary variables remain in a second subset, iteratively
13 performing the steps of:

14 determining the binary variables in the first subset that may
15 be rounded down without violating a performance constraint,
16 thereby forming the second subset;

17 rounding down one or more second binary variables in the
18 second subset having a zero performance reward; and

19 rounding down a third binary variable in the second subset
20 having a highest ratio of a cost reward to the performance
21 reward if none of the binary variables in the second subset have
22 the zero performance reward; and

23 determining the upper bound according to the binary variables having
24 binary values; and

25 placing the data objects onto the nodes of the distributed storage system
26 using a data placement heuristic selected in accordance with the determined
27 lower and upper bounds.

1 2. (Currently Amended) The ~~computer implemented~~-method of claim 1 wherein the
2 integer program comprises the performance constraint and an objective of minimizing
3 a cost.

1 3. (Currently Amended) The ~~computer implemented~~-method of claim 1 wherein the
2 integer program models a data placement problem.

1 4. (Currently Amended) The ~~computer implemented~~-method of claim 3 wherein the
2 data placement problem seeks to minimize a cost of placing the data objects onto the
3 nodes of athe distributed storage system while meeting athe performance requirement
4 for athe workload.

1 5. (Currently Amended) The ~~computer implemented~~-method of claim 1 wherein the
2 step of rounding up the first binary variable within the first subset further comprises
3 calculating the cost penalty and the performance reward.

1 6. (Currently Amended) The ~~computer implemented~~-method of claim 5 wherein the
2 step of rounding down the one or more second binary variables within the second
3 subset further comprises calculating the performance reward.

1 7. (Currently Amended) The ~~computer implemented~~-method of claim 6 wherein the
2 step of rounding down the third binary variable within the second subset further
3 comprises calculating the cost reward.

1 8. (Currently Amended) A ~~computer implemented~~-method of determining bounds
2 for a minimum cost comprising the steps of:

3 solving an integer program using a relaxation of binary variables to
4 determine a lower bound for the minimum cost, the relaxation allowing the
5 binary variables to take values over the range of zero to one, a first subset of
6 the binary variables comprising the binary variables having values between

7 zero and one, the integer program modeling a data placement problem which
8 seeks to minimize a cost of placing data objects onto nodes of a distributed
9 storage system while meeting a performance requirement for a workload;
10 until no binary variables remain in the first subset, iteratively performing
11 the steps of:
12 calculating a cost penalty and a performance reward for each of the
13 binary variables in the first subset;
14 rounding up a first binary variable having a lowest ratio of the cost
15 penalty to the performance reward;
16 until no binary variables remain in a second subset, iteratively
17 performing the steps of:
18 determining the binary variables in the first subset that may
19 be rounded down without violating the performance
20 requirement, thereby forming the second subset;
21 calculating a cost reward and the performance reward for
22 each of the binary variables in the second subset;
23 rounding down one or more second binary variables in the
24 second subset having a zero performance reward;
25 rounding down a third binary variable in the second subset
26 corresponding to a highest ratio of a cost reward to the
27 performance reward if none of the binary variables in the
28 second subset have the zero performance reward; and
29 determining an upper bound for the minimum cost according to the binary
30 variables having binary values; and
31 placing the data objects onto the nodes of the distributed storage system
32 using a data placement heuristic selected in accordance with the determined
33 lower and upper bounds.

1 9. (Currently Amended) The ~~computer implemented~~ method of claim 8 wherein the
2 integer program further comprises a storage constraint.

1 10. (Currently Amended) The ~~computer implemented~~-method of claim 9 wherein the
2 step of determining the upper bound for the minimum cost further comprises the steps
3 of:

4 determining a particular node which uses a maximum amount of storage
5 within any evaluation interval; and
6 allocating the maximum amount of storage on all nodes for all evaluation
7 intervals.

1 11. (Currently Amended) The ~~computer implemented~~-method of claim 9 wherein the
2 step of determining the upper bound for the minimum cost further comprises the steps
3 of:

4 determining a maximum amount of storage for each node within any
5 evaluation interval; and
6 allocating the maximum amount of storage on each node for all evaluation
7 intervals.

1 12. (Currently Amended) The ~~computer implemented~~-method of claim 8 wherein the
2 integer program further comprises a replica constraint.

1 13. (Currently Amended) The ~~computer implemented~~-method of claim 12 wherein the
2 step of determining the upper bound for the minimum cost further comprises the steps
3 of:

4 determining a maximum number of replicas for any data object within any
5 evaluation interval; and
6 placing the maximum number of replicas for all data objects for all
7 evaluation intervals.

1 14. (Currently Amended) The ~~computer implemented~~-method of claim 12 wherein the
2 step of determining the upper bound for the minimum cost further comprises the steps
3 of:

4 determining a maximum number of replicas for each data object within

5 any evaluation interval; and

6 placing the maximum number of replicas for each data object for all
7 evaluation intervals.

1 15. (Original) A computer readable memory comprising computer code for
2 implementing a method of determining bounds for a minimum cost, the method of
3 determining the bounds for the minimum cost comprising the steps of:

4 solving an integer program using a relaxation of binary variables to
5 determine a lower bound for the minimum cost, the integer program
6 comprising a performance constraint and an objective of minimizing a cost,
7 the binary variables having values between zero and one comprising a first
8 subset;

9 for the binary variables within the first subset and until no binary variables
10 remain in the first subset, iteratively performing the steps of:

11 rounding up a first binary variable having a lowest ratio of a cost
12 penalty to a performance reward; and

13 until no binary variables remain in a second subset, iteratively
14 performing the steps of:

15 determining the binary variables in the first subset that may
16 be rounded down without violating the performance constraint,
17 thereby forming the second subset;

18 rounding down one or more second binary variables in the
19 second subset having a zero performance reward; and

20 rounding down a third binary variable in the second subset
21 having a highest ratio of a cost reward to the performance
22 reward if none of the binary variables in the second subset have
23 the zero performance reward; and

24 determining an upper bound for the minimum cost according to the binary
25 variables having binary values.

1 16. (Original) The computer readable memory of claim 15 wherein the integer

2 program models a data placement problem.

1 17. (Previously Presented) The computer readable memory of claim 16 wherein the
2 data placement problem seeks to minimize a cost of placing data objects onto nodes
3 of a distributed storage system while meeting a performance requirement for a
4 workload.

1 18. (Previously Presented) The computer readable memory of claim 15 wherein the
2 step of rounding up the first binary variable within the first subset further comprises
3 calculating the cost penalty and the performance reward.

1 19. (Previously Presented) The computer readable memory of claim 18 wherein the
2 step of rounding down the one or more second binary variables within the second
3 subset further comprises calculating the performance reward.

1 20. (Previously Presented) The computer readable memory of claim 19 wherein the
2 step of rounding down the third binary variable within the second subset further
3 comprises calculating the cost reward.

1 21. (Original) A computer readable memory comprising computer code for
2 implementing a method of determining bounds for a minimum cost, the method of
3 determining the bounds for the minimum cost comprising the steps of:

4 solving an integer program using a relaxation of binary variables to
5 determine a lower bound for the minimum cost, the relaxation allowing the
6 binary variables to take values over the range of zero to one, a first subset of
7 the binary variables comprising the binary variables having values between
8 zero and one, the integer program modeling a data placement problem which
9 seeks to minimize a cost of placing data objects onto nodes of a distributed
10 storage system while meeting a performance requirement for a workload;
11 until no binary variables remain in the first subset, iteratively performing
12 the steps of:

13 calculating a cost penalty and a performance reward for each of the
14 binary variables in first the subset;
15 rounding up a first binary variable having a lowest ratio of the cost
16 penalty to the performance reward;
17 until no binary variables remain in a second subset, iteratively
18 performing the steps of:
19 determining the binary variables in the first subset that may
20 be rounded down without violating the performance
21 requirement, thereby forming the second subset;
22 calculating a cost reward and the performance reward for
23 each of the binary variables in the second subset;
24 rounding down one or more second binary variables in the
25 second subset having a zero performance reward;
26 rounding down a third binary variable in the second subset
27 corresponding to a highest ratio of a cost reward to the
28 performance reward if none of the binary variables in the
29 second subset have the zero performance reward; and
30 determining an upper bound for the minimum cost according to the binary
31 variables having binary values.

1 22. (Original) The computer readable memory of claim 21 wherein the integer
2 program further comprises a storage constraint.

1 23. (Original) The computer readable memory of claim 22 wherein the step of
2 determining the upper bound for the minimum cost further comprises the steps of:
3 determining a particular node which uses a maximum amount of storage
4 within any evaluation interval; and
5 allocating the maximum amount of storage on all nodes for all evaluation
6 intervals.

1 24. (Original) The computer readable memory of claim 22 wherein the step of

2 determining the upper bound for the minimum cost further comprises the steps of:
3 determining a maximum amount of storage for each node within any
4 evaluation interval; and
5 allocating the maximum amount of storage on each node for all evaluation
6 intervals.

1 25. (Original) The computer readable memory of claim 21 wherein the integer
2 program further comprises a replica constraint.

1 26. (Original) The computer readable memory of claim 25 wherein the step of
2 determining the upper bound for the minimum cost further comprises the steps of;
3 determining a maximum number of replicas for any data object within any
4 evaluation interval; and
5 placing the maximum number of replicas for all data objects for all
6 evaluation intervals.

1 27. (Original) The computer readable memory of claim 25 wherein the step of
2 determining the upper bound for the minimum cost further comprises the steps of;
3 determining a maximum number of replicas for each data object within
4 any evaluation interval; and
5 placing the maximum number of replicas for each data object for all
6 evaluation intervals.